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Natural Purification of Streams

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It may be safely assumed that there are few natural waters on the surface of the earth that do not receive a perceptible amount of the sewage, drainage, or waste resulting from human activity and habitation. Now the experience of the human race has shown that many of these natural bodies of water are used as a source of water supply by considerable populations without any strikingly noticeable injurious effects. If all the dangerous elements, or, to put it more specifically, all the pathogenic bacteria, entering bodies of water remained there in their original numbers without change it needs little imagination to picture the difficulty there would be in obtaining a supply of even moderately wholesome drinking water. We know that this is not the case, and it is apparent that in nature some sort of change occurs which results in the destruction or disappearance of the offensive and disease-producing elements that are introduced from time to time into most bodies of water

It has been wittily said that what is wanted in a drinking water is innocence rather than repentance, but it must be remembered also that very few large communities are in a position to obtain a virginally pure supply. In practically every civilized country the rivers, large and small, receive the sewage or drainage of a more or less extensive population, and the same is true of the large ponds and lakes. It has been estimated by Hazen that the water supplied to approximately 52 per cent. of the urban population (in cities of over 25,000) of the United States is unsatisfactory. The large and increasing consumption of water by the inhabitants of modern cities and towns renders the obtaining of a sufficient quantity of uncontaminated water always difficult and in most cases impossible. For the majority of public water supplies recourse is had to sources known to be more or less polluted at some stage in their history. The reckless practise of some cities in using such water without artificial purification shows that a considerable degree of natural purification must occur, otherwise the consequences of the neglect of elementary precautions would be far more disastrous than they are.

The extent and rapidity of this process of natural purification are, however, questions upon which there has been much difference of opinion among sanitarians, and concerning which existing data are inadequate and in some cases apparently conflicting. The final settlement of the question hinges upon many imperfectly understood and variable factors.

The problem is often presented in concrete form as follows: Suppose a city pours its untreated sewage into a river, how far below the point at which the sewage is discharged is it permissible or desirable on sanitary grounds for another city to take its water supply from this stream? Or, in another relation, in the case of a city deriving its water supply from a river, how far above this point can another city be equitably and safely allowed to empty its sewage into the river? Under actual conditions pollution and subsequent purification never present themselves in so simple a form. Between the point of great pollution and that of derivation of the water supply other sources of contamination and infection almost invariably exist. The drainage from rural communities or from isolated farm houses connected, it may be, with outhouses immediately overhanging the tributaries of the main stream, constitutes a perpetual menace to the purity of river water, even when the possibility of pollution with urban sewage is removed. These often overlooked sources of danger are, however, frequently overshadowed by the grosser defilement to which a stream is subjected by the discharge of the sewage of a great city. It is the latter event that is commonly considered, although perhaps unwisely, as the main feature in the problem of the natural purification of streams.

Stripped of all technicalities the question at issue in the suit on the Chicago Drainage Canal really is how far can typhoid bacilli travel in the water of a particular flowing stream and arrive in such a condition as, in the legal phrase, "to constitute a menace and a danger" to the inhabitants of a distant city or state. It is obvious that the problem is not one of space so much as of time, that it is not so much the distance over which a bacillus has to pass as it is the time consumed in traversing the stretch of river between the two points. The problem at bottom is essentially that of the longevity of the typhoid bacillus in a given water, whether of a river or a lake. As is well

known, the conditions affecting this longevity are many and varied, and the experimental evidence shows that the length of life of this micro-organism is greater in some waters than in others and is influenced by a variety of concomitant conditions. Practically, then, every inquiry into the alleged self-purification of streams must partake of the nature of an independent and separate investigation, and must for the present be carried on without too much reference to the results obtained under other conditions. It has rarely been found possible to experiment directly with the typhoid bacillus under conditions identical with those obtaining in a given river. It is therefore necessary to rely provisionally upon data of an indirect and inferential character, and it is these latter only that are ordinarily considered in a study of any particular case. The indirect evidence is of several kinds and of different degrees of value.

Evidence regarding the causation of typhoid fever is often most cogent on the epidemiological side. The sewage of the city of Lowell, Massachusetts, is emptied into the Merrimac river only nine miles above the intake of the Lawrence water works, and it has been shown that on several occasions a large amount of typhoid fever in the former city was followed by an increase in the disease in Lawrence, the correspondence in time being so close as to satisfy epidemiological requirements. Apparently a similar relation existed between an outbreak of typhoid fever in Newburyport and an unusual infection of the Merrimac by the sewage of Lowell and Lawrence respectively 26 and 17 miles above. (Sedgwick, Report Mass. State Bd. of Health, 1892, p. 701.) No such relation could be traced between the prevalence of typhoid fever in Chicago and St. Louis. If such a connection obtained it would be supposed that the curves of the disease would be much alike and that the St. Louis curve would be slightly retarded in time. As a matter of fact a comparison made by the writer of the published deaths from typhoid fever in these two cities by months and by years showed no relation whatever. Sometimes the Chicago minimum and maximum rates precede those for St. Louis by a period of from 2 to 11 months, sometimes they follow the latter, and sometimes they coincide with them. A similar outcome attended the attempt to connect high water or low water stages in the Illinois river with typhoid fever in St. Louis. An

interesting comparison was made between the months of July-November, 1901 and July-November, 1902. The water in the Illinois river was nearly twice as high in this period in 1902 as in 1901, and yet the amount of typhoid fever in St. Louis in the latter part of these years was almost exactly the same. Again there were 222 deaths from typhoid fever in St. Louis reported in 1902 and 225 in 1904 while in Chicago there were more than twice as many in 1902 [801] as in 1904 [373].

An examination of the monthly deaths reported from typhoid fever in Chicago and St. Louis between 1890 and 1904 inclusive showed that the mortality in St. Louis could not be related in any way to the extent of mortality in Chicago, to the season of the year or to the stage of water in the Illinois river.* In this crucial test the epidemiological evidence fails to reveal any connection, direct or indirect, between the prevalence of typhoid fever in Chicago and its prevalence in St. Louis.

The analytical data may next be considered. It is my opinion that the ordinary chemical sanitary water analysis, at its best of doubtful value, is not well adapted for throwing much light upon the problem of the self-purification of streams. The chlorine determination can have practically no significance, and even the determination of the nitrogen compounds is of little real importance. It cannot be said that the process of decomposition and the processes that lead to the destruction of dangerous bacteria run a strictly parallel course either in septic tanks or in polluted rivers.

It is also true that the mere number of bacteria in a water is no absolute criterion of the purity of the water. At the same time it must be admitted that the fate of typhoid bacilli introduced into a river is probably more closely correlated with that of other sewage bacteria than with oxidation changes in chemical constituents. The diminution in the numbers of bacteria in the Desplaines and Illinois rivers from Chicago to Grafton is shown in the following table:

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*Record of Testimony, pp. 6278-6284.

DESPLAINES AND ILLINOIS RIVERS, CHICAGO TO GRAFTON.

Stations. Collecting	Distance from Bridgeport in Miles.	No. of Colonies per c. c.	No. of determinations.
Bridgeport	0	1,245,000	19
Lockport	29	650,000	30
Joliet	33	486,000	28
Morris	57	439,000	26
Ottawa	81	27,400	26
LaSalle	95	16,300	31
Henry	123	11,200	29
Averyville	159	3,660	30
Wesley City	165	758,000	22
Pekin	175	492,600	29
Havana	199	16,800	26
Beardstown	231	14,000	26
Kampsville*	288	4,800	19
Grafton	318	10,200	28

There is no reason to suppose that the typhoid bacillus is any more resistant than the average sewage bacteria, and the enormous reduction in the numbers of the latter shown in the table would seem to indicate a similarly high and speedy mortality among typhoid bacilli introduced into a flowing stream.*

Special significance, in the judgment of the writer, attaches to the relative abundance of *B.coli* in a river water at different points along its course. This micro-organism, as is well known, is a normal inhabitant of the healthy human intestine and is found in large numbers in fresh sewage where, by appropriate methods, it is usually detected in each 1-10000 c. c. examined. A progressive diminution in the numbers of colon bacteria is observed in the samples of water taken at various points along the Illinois river from Lockport to Averyville, just above Peoria. At this latter point the colon bacillus is rarely found in 1-100 c. c. of the river water and is absent in 1 c. c. in about 25 per cent of the examinations. The considerable addition of bacteria to the river water from Peoria

*The longevity of typhoid bacilli in water as indicated by experiment is considered elsewhere by Professor Russell and the writer.

sewers, stockyards, and distilleries causes a temporary increase in both the total bacterial and the colon content; but this in turn disappears and *at Grafton, at the mouth of the Illinois river, the number of colon bacteria in the water is no greater than the number at Averyville* 160 *miles above, and no greater than the number in the various large tributaries of the Illinois.* If it be true that the fate of the colon bacillus in running water furnishes the most satisfactory indication we can secure at present of the continuance of vitality of the typhoid bacillus, there can be no hesitation as to the conclusions to be drawn from this investigation. Since this near biological relative of the typhoid bacillus perishes speedily and in large numbers in the course of the Illinois river, there is reason to suppose that the typhoid bacillus itself does not long survive exposure to the same conditions.

Furthermore, when it is a question of comparing the condition of the Illinois river at its mouth with that of the Missouri river at its mouth and of the Mississippi just above its union with the Illinois, it is found that, judged by the colon content, the Illinois is about on a par with the Mississippi and notably superior to the Missouri. The characters of these several waters remain more or less distinct, in spite of some mixing, as shown by samples taken at approximately equidistant points across the Mississippi river at the St. Louis water intake. Photographs in the Record of the Case (pp. 6127-6130) illustrate the conditions there observed. All these facts indicate (1) That under the conditions prevailing in the Illinois river few if any typhoid bacilli live long enough to make the passage from Chicago to St. Louis; (2) That the water of the Missouri river, which constitutes by far the larger proportion of the St. Louis water supply, is, if weight be given to the colon content, more likely to contain disease germs than the combined waters of the Illinois and the Mississippi; (3) That in view of the discharge of untreated sewage into the Mississippi and Missouri rivers at Alton, St. Charles, and many other towns and cities much nearer to the St. Louis intake in point of time than Chicago, it is more reasonable to attribute any excess of typhoid fever in St. Louis to these near sources of infection than to any community, however large, situated at a remote point; (4) That the available evidence, bacteriological

and epidemiological, does not support the hypothesis of a connection between the opening of the Chicago Drainage Canal and the amount of typhoid fever in St. Louis.

Considered as a general proposition, the self-purification of streams has received more attention than its practical importance would appear to warrant. Under actual conditions implicit reliance on the natural purification of a river water is usually misplaced. A stream may conceivably rid itself of infection, if such infection be introduced at only one point, but may, nevertheless, be so exposed to contamination at other points along its course as to be totally unfit as a source of public water supply. Efficient control over the water sheds of such streams as the Mississippi, Illinois, and Missouri is obviously quite impracticable. It is only under such very unusual conditions as exist along the lower Mississippi that a river has a chance to work out its own salvation. If continuous contamination be withheld for a certain number of miles, or rather days, then "self-purification" may become a factor worthy of consideration. Such a condition is evidently rare.

The other extreme of opinion is equally untenable. Such an assertion as the following has been made, that "water once polluted is unsafe for domestic use unless artifically purified." No such sweeping statement can be justified unless based on a belief in the immortality of disease germs. All that we know about the bacteria of water-borne diseases goes to prove that they never multiply in water even when this is highly polluted, that they die out rather rapidly, and that even the few more resistant individuals lose their virulence and do not long retain their power of producing infection.

It may sometimes be difficult to determine which is the more reprehensible practise, discharging untreated sewage into a stream or lake or delivering unpurified water to a trustful public. Either procedure may be temporarily unavoidable.